Preparing for penguin analyses needed arising from comments from the 2019 and previous International Stock Assessment Workshops

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Summary

A summary is provided of issues that need to be considered in planning further analyses needed of penguin data that might provide a basis for penguin-related management recommendations. These issues include the data (and particularly co-variate values) available, the conduct of two- and one-stage estimation approaches, and the relation of possible response variable changes in response to island closures to penguin population growth rates.

Introduction

The outcome from the 2019 IWS raises a number of issues that will need to be taken into account in the further analyses required to provide a basis for management recommendations related to penguins, and in particular in relation to further possible island closures.

The purpose of this document is to provide an initial attempt to set out these issues in a structured manner, so as to facilitate organisation and conduct of those analyses in an efficient manner.

Data

FISHERIES/2019/NOV/SWG-PEL/23 lists the values of the aggregated data that are available for the evaluation of the Island Closure experiment. The response variables and the islands for which they are available are as follows (***W***= west coast, Robben and Dassen; ***S***= south coast Bird and St Croix);

1) Fledging success — ***W***
2) Chick growth rates — ***W***
3) Active and potential nests — ***W***
4) Chick condition — ***W*** and ***S***
5) Foraging path length — ***W*** and ***S***
6) Foraging trip duration — ***W*** and ***S***
7) Maximum distance foraged — ***W*** and ***S***

In addition, this document mentions that disaggregated data are available for some of these data sets, and that such disaggregated data are available for chick survival for ***W***.

The 2019 IWS Panel state that: "The set of covariates to consider in the analyses should be identified by the relevant DEA working group."

There needs to be a listing for each of the data sets above of what co-variates are provided for each response variable in the disaggregated data available, followed by a PWG (or appointed TT) decision on which are to be included in analyses. Note that FISHERIES/2019/NOV/SWG-PEL/23 does already include pertinent biomass estimates from sardine and anchovy recruitment and November surveys.

Two stage approaches (i.e. based on annually aggregated response data)

For the ***S*** islands, analyses have already been conducted for the most recent data for response variables 4) to 7), as reported in FISHERIES/2019/NOV/SWG-PEL/27rev and SWG-PEL/33.

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However, these might perhaps be desirably revised to account for certain co-variates through use of standardisation approaches for the input to the analyses. If so there needs to be discussion about which co-variates are desirably considered for inclusion in that standardisation.

For the ***W*** islands, the PWG's currently agreed approach, as developed in collaboration with previous IWS Panels, is as last reported in FISHERIES/2016/DEC/SWG-PEL/77rev. Those analyses considered response variables 1), 2), 4) and 7). The following questions arise regarding updating this analysis to take more recent data into account:

a) For the same or an amended list of response variables?
b) For nominal or standardised annual index values; if the latter, which co-variates are desirably considered?
c) Can this approach be extended to the ***S*** islands?

One stage approaches (i.e. based on "individual" data in a single estimation process)

FISHERIES/2019/NOV/SWG-PEL/32 provides examples of such approaches.

The 2019 IWS Panel stated: "Given the nature of the experiment, use of individual data is to be preferred. However, this is only the case if an appropriate random effects structure is chosen." and that "Model selection methods should be applied to select an appropriate random effects structure.".

The 2016 IWS Panel stated that for estimation based on such disaggregated data: "The estimator should be based on a multiplicative rather than additive model (i.e. Equation 1 of MARAM/IWS/DEC16/Peng_Clos/P2) with log-normal or gamma errors (for indices that can be negative, add a constant equal to the mean of the data)."

The following questions therefore arise concerning further analyses:

a) What alternative random effects structures need to be considered?
b) What multiplicative model is to be applied, and how are negative values of response variables to be addressed?
c) To which response variables and islands is this approach to be applied?

Relating closure effects (possible changes to values of response variables) to penguin population growth rates

This issue has often been raised by IWS Panels:

2019 Panel: "The Panel **recommends** shifting the debate from estimation methods to the consequences of the estimates. Thus, it is important to conduct projections of penguin population dynamics given the estimates from the current studies (particularly chick survival) and measures of their uncertainty."

2016 Panel: "The Panel noted that a threshold based on population dynamics models had been selected for one of the response variables (fledging success) while the thresholds for the other response variables had been selected by an assumption of proportionality with reproductive success. Four papers (Boresma and Rebstock. 2009; Hennicke and Culik, 2005; Horswill et al., 2014; McClung et al., 2004) were made available during the workshop that showed relationships between predator mass and survival. The Panel recommended that they be considered by the Pelagic Working Group. The Panel noted that the analyses have not attempted to integrate information across the response variables. However, while chick condition and chick growth are likely correlated, chick condition/growth and fledgling success affect processes that are sequential in the life history of penguins, which means that a fishery effect on each of chick condition/growth and fledgling success in combination could lead to a biologically meaningful population effect. Moreover, increases in forage trip length due to fishery impacts may have negative consequences for adult survival."

2015 Panel: Analyses should be conducted for multiple effect sizes for each response variable. The models for the response variables should be designed so the values for the effects of fishing, λ (and/or δ), are such that a larger value means a greater negative impact of fishing near islands on penguin population growth rate. The lowest effect size to be evaluated (the "threshold") (e.g., 0.1 in Fig. 1) should be computed using a population dynamics model such as the simple model in MARAM/IWS/DEC15/PengD/BG4 or the penguin population dynamics developed by Robinson et al. (2015) given a management objective of a pre-specified change in population growth rate following elimination of fishing near islands (and assuming that fishing impacts only one population dynamics parameter). All six response variables should be assessed with respect to how reliably they are sampled and how informative they are regarding potential fishery effects on population growth rates. One of these variables (fledgling success) is directly related to the net reproduction rate, while the other five response variables are related only indirectly. It may still prove challenging to develop thresholds for the indirect response variables because it may be unclear how to quantify how changes in the variables impact biological processes and hence population growth rate (e.g. the relationship between trip duration and population growth rate). A response variable should not be considered further if there is no (objective) way to determine a threshold for it. In addition, if a particular response variable is sub-ordinate or directly correlated with another then there may be little to be gained by considering it further.

Issues that consequently need to be addressed are:

a) How might (changes in) each of the response variables under consideration be related to penguin population growth?
b) The threshold for the "effect of fishing/closure" parameter λ (and/or δ) is currently agreed to be 0.1. Does this need review?

Note that the text headed "Effect size" which follows on the next page explains the basis on which this value of 0.1 was chosen. It is copied from Appendix B of MARAM/IWS/DEC14/Peng/B4.

Effect size

Effectively the approach outlined above is taking the effect size for the power analysis to be equal to the current best estimate of the fishing effect parameter λ_i under the random year effects model. This does however raise the problem that if that estimate is very small (perhaps so small as not to be meaningfully different from zero biologically), it is of no real interest to ascertain the exact value of the rather large number of years which would be needed to collect sufficient data to determine that the value had been distinguished from zero at the 5% significance level.

Instead therefore, for cases where the point estimate of λ_i is small, it has been replaced by a fixed value, of the same sign as the point estimate of λ_i, but of a magnitude which is (arguably) biologically meaningful. The actual fixed value chosen is 0.1. The justification for this choice comes from the following consideration of penguin population dynamics.

If penguin reproductive maturity is assumed to occur at age 4, the basic equation used by Robinson (2013) for the mature female component of the population (numbering N in year y) may be written:

$$N_{y+1} = N_y S + H_{y-3} S^3 N_{y-3} \tag{B.3}$$

where S is the mature female annual survival proportion and H is a measure related to the product of egg production and fledging success. In a situation where the population is changing at a steady rate:

$$\eta = N_{y+1}/N_y \tag{B.4}$$

then

$$\eta^4 = \eta^3 S + H S^3 \tag{B.5}$$

which if H changes by ΔH leads to a corresponding change in penguin growth rate $\Delta\eta$ given by:

$$\Delta\eta = \frac{S^3}{4\eta^3 - 3\eta^2 S} \Delta H \tag{B.6}$$

Now results in Robinson (2013) suggest that for S=0.88, the Robben island penguin population abundance was approximately steady, so that substituting η=1 in equation (B.5) yields H = 0.176, and hence from equation (B.6):

$$\Delta\eta/\eta = 0.088\ \Delta H/H \tag{B.7}$$

Now from differentiating equation (B.1), the relative change in the penguin response variable F arising from a suspension of fishing (C changes from $\bar{C}$ to 0) will be given by:

$$\Delta F/F = -\lambda \tag{B.8}$$

so that if one assumes as a first approximation that a relative change in F results in the same relative change in H (i.e. $\Delta H/H = \Delta F/F$), it then follows that:

$$\Delta\eta/\eta = -\ 0.088\ \lambda \sim -0.1\lambda \tag{B.9}$$

If then 1% is to be regarded as a meaningful change in the penguin population growth rate (to be achieved, conceivably, by a suspension of fishing in the neighbourhood of the colony concerned), it follows that the corresponding value for the magnitude of λ is about 0.1, which is why this value was chosen for what is in effect a default minimum effect size above.